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A Study of the Relative Values of the Audito-Vocal Forward Span and the Reverse Span as Diagnostic Tests

SELINDA McCAULLEY

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A STUDY OF THE RELATIVE VALUES OF THE AUDITO-VOCAL FORWARD MEMORY SPAN AND THE REVERSE SPAN AS DIAGNOSTIC TESTS

SELINDA MCCAULLEY
Department of Special Education, Philadelphia

The Psychological Clinic of the University of Pennsylvania, under the direction of Dr. Lightner Witmer, has studied and stressed the value of memory span tests for diagnostic purposes more than any other psychological clinic. Humpstone[1] was the first member of the clinic to emphasize its value, to attempt to analyze the abilities tested and to point out its value in educational work. He established the norm for first grade proficiency, holding that "above 5 or 6 years, or the first grade, one should have a span of 5 or more." A. S. Starr[2] corroborates Humpstone's findings and concludes that "the span expresses the index of proficiency of the co-functioning of all the mental competencies involved, and is not a measure of a single mental ability. Since the co-functioning of this particular complexus is most essential to social adequacy, the diagnostic value of the audito-vocal digit memory span is thereby augmented. In general, mental development varies directly as the ratio of the reverse span to the forward span."

The history of the origin and the development of the memory span test, presented in the introduction of Dr. Starr's study is so complete that no space will be given here to repeat what has been so ably done.

Brotemarkle[3] emphasizes the fact that (1) "the diagnostic value of the memory span test is readily evidenced in the manner in which it clearly differentiates the two extreme groups, the upper and the lower. (2) The memory span test is diagnostic of the complexity of mental organization taken as a bodily factor, including the competencies with which the individual makes for successful performance. . . . . (5) The memory span test has a certain restriction placed upon its use by the intellectual level of the individual being tested. This is clearly noted in the varying diagnostic values of the different types of memory span. Further research in this field should reveal the relative diagnostic use of the different types of memory span tests at the varying intellectual and age levels."

Problem

In presenting this study the writer has attempted to show the value of the forward audito-vocal digit memory span test and the reverse digit span test as diagnostic tests, not only as separate tests but in their relation one to the other.

With this purpose in mind a study was made of a thousand children, who, because of inability to make normal progress in school, had been referred to the psychological clinic connected with the Division of Special Education, Board of Public Education, Philadelphia. This group contains only children who were recommended for backward classes, or, in the case of the older children, special classes connected with the high schools. Complete individual examinations, including performance tests, school proficiency tests and the Binet Test, were given in every case. Special note was made of their forward and reverse spans as well as to their I.Q. In addition all the teachers in four different representative public schools were asked to send to the examiner the three pupils in her class who were doing the most successful school work and the three pupils who were doing the least successful work. These children were from grade one to grade eight, and were presumably of normal mentality. The forward and reverse spans of this group consisting of 534 children were obtained individually. This group includes both white and negro children, the larger per cent being white. There are children of almost every nationality; the majority of the group are native born. In so far as possible the attempt was made to select children who would be fairly representative of a community of a medium social and economic level.

Method

The memory span tests were in every case given individually, according to the standard method of procedure. After the child had been put at his ease, he was asked to "say these numbers just as I say them," whereupon a series of two digits was given. When the response was correct, another series, increased by 1 digit, followed, and this procedure was repeated until the child failed to repeat correctly. The highest number of digits correctly reproduced upon a single presentation was considered to be the forward digit span. One correct response out of 3 trials was required. The series used were the same as those used at the University of Pennsylvania Psychological Clinic, in which no digit follows another digit in either the natural or reverse sequence, and in which the

RETARDED GROUP

TABLE 1. AUDITORY DIGIT SPAN FORWARD

Age	*Forward Span*									
	9	8	7	6	5	4	3	2	1	Total
19					2					2
18				3						3
17		3	2	4	3					12
16	2	3	7	11	7	3	1			34
15	1	5	26	47	36	10				125
14		3	11	44	46	7	1			112
13			10	39	51	15	2	1		118
12			12	33	55	21	2			123
11		1	3	26	49	19	1	1		100
10			1	11	54	32	2	1		101
9		2	1	9	42	34	9			97
8				7	33	35	7			82
7		1?		2	14	31	11	1		60
6					9	13	8		1	31
5										
Total	3	18	73	236	401	220	44	4	1	1000

TABLE 2. AUDITORY DIGIT SPAN REVERSE

Age	*Reverse Span*							Total
	7	6	5	4	3	2	0	
19					2			2
18		1	2					3
17			7	2	3			12
16		2	13	8	5	5	1	34
15		1	25	53	35	10	1	125
14			10	43	52	6	1	112
13			3	37	58	14	6	118
12			3	36	63	20	1	123
11				7	70	18	5	100
10				11	56	23	11	101
9				3	47	28	19	97
8				2	32	29	19	82
7					5	20	35	60
6						5	26	31
5								
Total		4	63	202	428	178	125	1000

digits form no meaningful association (as 1 4 9 2, etc.). The digits were presented distinctly, without rhythm or emphasis, at the rate of three in two seconds.

RETARDED GROUP

TABLE 3. AUDITORY DIGIT SPAN FORWARD—I. Q.

I. Q.	*Forward Span*									Total
	9	8	7	6	5	4	3	2	1	
110–120		1		2	2					5
100–110		2	1	8	9	5	1			26
90–100		6	10	32	50	21	1			120
80– 90		5	18	63	102	40	6			234
70– 80	3	3	27	75	131	68	15	1		323
60– 70		1	14	42	80	60	6			203
50– 60			2	13	24	18	9			66
40– 50			1	1	3	8	4		1	18
30– 40							2	2		4
20– 30								1		1
Total	3	18	73	236	401	220	44	4	1	1000

TABLE 4. REVERSE DIGIT SPAN—I. Q.

I. Q.	*Reverse Span*							Total
	7	6	5	4	3	2	0	
110–120			1	1	3			5
100–110		1	1	5	7	6	6	26
90–100		1	17	24	47	18	13	120
80– 90		1	17	69	96	38	13	234
70– 80		1	24	69	139	59	31	323
60– 70			3	30	110	32	28	203
50– 60				4	24	18	20	66
40– 50					2	7	9	18
30– 40							4	4
20– 30							1	1
Total		4	63	202	428	178	125	1000

After the forward span had been determined, the examiner said, "Now I want you to say these numbers in a different way. Do not say them as I do, but say them backwards. For instance, if I say 7, 1, you say 1, 7. Do you understand? What will you say if I say 4, 9?" After a correct response, "and 6, 2? Right. Now say this one backwards, 4, 2, 7." The same series as are

used in the Binet Simon Test (Stanford Revision) were used. The highest number of digits correctly reversed determined the reverse span.

GOOD GROUP—REGULAR GRADES

TABLE 5. AUDITORY DIGIT FORWARD SPAN

Age	*Memory Span*								Total
	9	8	7	6	5	4	3	2	
16									
15									
14		2	2	2					6
13	3	7	7	6	1				24
12	2	6	4	6	2				20
11	1	9	7	19	8				44
10	4	9	13	11	2				39
9	4	4	2	9	7				26
8	1	3	5	20	11				40
7		3	3	10	14	3			33
6		3	1	4	17	6			31
5				2	1	1			4
Total	15	46	44	89	63	10			267

TABLE 6. AUDITORY DIGIT REVERSE SPAN

Age	*Memory Span*							Total
	7	6	5	4	3	2	0	
16								
15								
14			5	1				6
13	1	7	14	2				24
12	2	3	9	5	1			20
11		3	18	19	3	1		44
10		5	9	22	3			39
9		4	5	11	6			26
8			7	16	15	2		40
7			2	11	19	1		33
6		1		6	15	9		31
5					4			4
	3	23	69	93	66	13		267

The span was considered normal for age if it met the requirements in The Stanford Revision of the Binet-Simon Tests,

POOR GROUP—REGULAR GRADES

TABLE 7. AUDITORY DIGIT FORWARD SPAN.

Age	*Memory Span*								Tota
	9	8	7	6	5	4	3	2	
17				1	1				2
16			1						1
15		2	2	8	9				21
14	1	2	8	11	8	2			32
13	1	6	5	10	17				39
12			5	8	5	1			19
11		5	1	8	7	3	1		25
10			1	5	9	2			17
9		2	1	7	15	2			27
8		2	2	9	7	9	1		30
7			1	7	8	13	1		30
6				2	6	12	1	1	22
5					1		1		2
Total	2	19	27	76	93	44	5	1	267

TABLE 8. AUDITOR DIGIT REVERSE SPAN.

Age	*Memory Span*							Total
	7	6	5	4	3	2	0	
17				2				2
16				1				1
15	1		4	6	8	2		21
14		1	4	12	11	4		32
13		2	4	16	15	2		39
12		1	1	5	9	3		19
11				7	10	8		25
10				2	8	7		17
9				4	16	7		27
8				4	10	12	4	30
7				1	8	13	8	30
6						6	16	22
5						1	1	2
Total	1	4	13	60	95	65	29	267

i.e., a forward digit span of 5 is normal for children of 7, 8, and 9 years of age (see Table 11).

The results have been divided into 3 parts:

(1) The forward and reverse audito-vocal digit spans obtained

from children who were referred to the clinic because of recognized inability to compete in the normal group. (Tables 1, 2, 3, 4)

(2) The forward and reverse audito-vocal digit spans obtained from children who were markedly successful in competition in the normal group. (Tables 5 and 6)

(3) The forward and reverse audito-vocal digit spans obtained from children who were least successful in making the progress demanded of them in the normal group. (Tables 7 and 8)

AGE GRADE TABLES

TABLE 9. GOOD GROUP

Grade	Age													Total
	17	16	15	14	13	12	11	10	9	8	7	6	5	
8				6	17	6	1							30
7					4	9	16	1						30
6					3	4	16	10						33
5						1	8	19	8					36
4							3	9	14	7				33
3									3	26	4			33
2									1	6	20	6		33
1										1	10	24	4	39
Total				6	24	20	44	39	26	40	34	30	4	267

TABLE 10. POOR GROUP.

Grade	*Age*													Total
	17	16	15	14	13	12	11	10	9	8	7	6	5	
8	2	1	9	13	5									30
7			6	8	11	3	2							30
6			5	8	13	3	2	2						33
5			1	3	5	11	12	4						36
4					4	1	7	10	11					33
3					1	1	2		15	14				33
2								1	2	12	16	2		33
1										3	14	20	2	39
Total	2	1	21	32	39	19	25	17	28	29	30	22	2	267

Tables 1 and 2 indicate clearly how dependent the length of span is upon age, while Tables 3 and 4 indicate how dependent either is upon mental development. The diagnostic significance of this test is also strikingly evident; although at each age level in the retarded group, there are some few individuals who have nor-

mal spans for their age, in only three instances (forward span, 9 and 6 year level; reverse span, 8 year level) is the mode equivalent to the age norm. (Table 11)

TABLE 11. MODAL DISTRIBUTION.

Age	Good Group		Poor Group		Retarded Group		Norm	
	Forward	Reverse	Forward	Reverse	Forward	Reverse	Forward	Reverse
16					6	5	7	6
15			6	3	6	4	7	5
14			6	4	6	4	7	5
13	7–8	5	6	4	5	3	6	5
12	8–6	5	6	3	5	3	6	5
11	6	4	6	3	5	3	6	4
10	7	4	5	3	5	3	6	4
9	6	4	5	3	5	3	5	4
8	6	4	4	2	4	3	5	3
7	5	3	4	2	4	0	5	3
6	5	3	4	0	4	0	4	

Of this group 33.2 per cent have an audito-vocal forward span equal to or better than their age norm, while only 10.9 per cent have a reverse span equal to their age norm. It is therefore evident that both tests are of significant diagnostic value, but that the reverse span better differentiates the poor or retarded group.

In this group 32.3 per cent have I.Q.'s between 70 and 80, 3.1 per cent have I.Q.'s of 100 or more and 2.3 per cent have I.Q.'s below 50. Seventy-six per cent, or the modal group, have I.Q.'s ranging from 60 to 90.

Of the entire group approximately 40 per cent have a forward span of 5 and a reverse of 3, which is considered the norm for a seven-year-old child. Only 33 per cent were actually able to give a forward span better than 5 digits, while 73 per cent should have given a forward span better than 5, according to their age norms.

In the reverse span test only 26.9 per cent were able to give a reverse span better than 3, while according to their age norms 82.7 per cent should have been able to give a reverse span better than 3.

Over one-fourth of the entire group (26.9 per cent) were unable to give a forward span of 5 digits and 30.3 per cent of the entire group were unable to give a reverse span of 3 digits. According to their age norms only 3.1 per cent should have failed to give 5 digits forward, and 3 digits in reverse order.

A comparison of the modal distribution of this group with the modal distribution of Dr. Starr's group of retarded children shows an agreement at every age level except age 8 and age 13 (a difference of 1 digit.) If these results, amounting to 3,000, should be massed, they would give an accurate picture of the modal memory span of retarded children at every age level from 6 to 16 years.

A comparison of the results obtained from the two groups of children in the regular grades (Tables 5 to 8) again shows definitely that the length of the memory span both forward and reverse depends on age and mental development. It also shows a decided positive relationship between an adequate memory span and ability to do successful school work.

In the good group 92.1 per cent of the children had a forward span equal to or better than their age norm, while in the poor group only 57.3 per cent had a forward span equal to or better than their age norm. In the good group 90.2 per cent had a reverse span equal to or better than the age norm, while in the poor group only 23.2 per cent were able to give a reverse span equal to or better than their age norm.

A comparison of these results also emphasizes the fact that of the two spans the reverse is of greater diagnostic value.

In connection with these two tables a study of an age-grade chart for the same two groups is significant. (Tables 9 and 10) In the good group the ages run from 5 to 14 years, in the poor group, from 5 to 17 years. In the good group 59 cases or 22 per cent are 1 or 2 years over-age for grade. This over-ageness can in most cases be explained by a late entrance, or to illness on the part of the pupil. In the poor group 184 cases or 69.9 per cent are from 1 to 5 years over-age for grade. Most of these children are "repeaters." In the good group 63 cases or 23.5 per cent are 1 or 2 years under-age for grade, while in the poor group only 8 cases or 2.9 per cent are 1 year younger than the grade norm.

Several interesting facts were brought out during the pursuit of this investigation. As a manner of form, although the examiner had been supplied by the teacher with the child's name, grade, and date of birth, the child was asked to supply this information, except that only the birthday and not the year was requested.

In no case did a child from the good group in the regular grades fail to correctly supply this information. In the poor group, however, 20 children, one of them a fifteen-year-old boy, could not give their correct birthdays.

Many people are under the impression that negro children invariably have high scores, particularly for the audito-vocal and audito-vocal-visual spans. This fact was not established in the present study. To be sure, the number of negro children is small, but it is fairly representative since the children were taken in a rather hit and miss fashion from the school group. The same fact is supported in a study of negro children made by Miss Mabel Farson, but as yet unpublished. From her study it may be concluded that the memory spans of negro children vary no more or less than do the memory spans among white children, but that they are dependent on age and mental ability.

The following is a summary of the memory spans of the negro children found in the regular grades in both the good and poor groups:

Grade	Age	Auditory Forward	Visual	Reverse
1	6 yr. 6 mo.	4	4	0
	6 yr. 0 mo.	4	4	0
2	8 yr. 8 mo.	6	6	3
	8 yr. 4 mo.	5	4	0
	8 yr. 2 mo.	6	7	4
	7 yr. 10 mo.	6	6	2
3	7 yr. 11 mo.	7	9	5
	9 yr. 4 mo.	6	7	3
	8 yr. 0 mo.	6	7	3
4	9 yr. 5 mo.	5	5	3
	10 yr. 9 mo.	5	8	3
5	10 yr. 6 mo.	6	6	3
	11 yr. 6 mo.	7	9	3
	13 yr. 6 mo.	6	7	4
	11 yr. 0 mo.	8	8	4
6	13 yr. 4 mo.	8	9	4
	14 yr. 10 mo.	4	6	2
	14 yr. 5 mo.	6	8	3
7	15 yr. 0 mo.	5	7	3

In one school five children from the same family were all referred in the poor group. They are of Italian origin, but native born. Their ages, grade and memory spans are as follows:

Name	Age	Grade	Forward auditory	Visual	Reverse
Mary	7 yr.	1A	4	2	0
Tony	8 yr. 10 mo.	2A	4	4	2
Frank	12 yr. 3 mo.	5A	5	7	3
Rachael	13 yr. 6 mo.	4A	5	6	2
Kate	14 yr. 11 mo.	6A	4	5	2

In the same school are two small boys who stand out as being decidedly superior to the entire group of 534 children, in fact as being decidedly superior children in any group.

One little boy with a chronological age of 7 years 2 months, and a mental age of 11 years 2½ months, I.Q. 156, had an auditory forward span of 8 and a reverse span of 4, sometimes 5. He has unusual language ability, and has invented a language of his own, which he and his mother talk.

The other little fellow, a most attractive, unusually gifted boy of 6 years 4 months, had a mental age of 10 years 5 months, I.Q. 165. His forward span was 8, reverse span 6. The first year he entered school he progressed from 1A to 2B by incidental promotions. He reads and comprehends at the Sixth Grade level.

These two boys have recently been examined in the Psychological Clinic at the University of Pennsylvania, and placed in the 1 per cent group of children, superior to 99 per cent.

In the literature there is some difference of opinion as to what ability or abilities are tested by the memory span test. Jacobs,[4] who first proposed and used the test, called it a test of prehension. Whipple[8] in his discussion states that it primarily tests the capacity for immediate reproduction after a single presentation, which capacity corresponds to what the Germans call "Merkfähigkeit." Humpstone[1] calls it a test of associability. Brotemarkle[3] states that "the memory span is of diagnostic value not alone because of its own simplicity, but also because of its use of the numerous mental factors of the attentional, imaginal, and associational fields—its use of mental complexity."

This fact is also stressed by Starr, who states that "the span expresses the index of proficiency of the co-functioning of all the mental competencies involved, and is not a measure of a single mental ability."

Memory span can best be defined as "the ability to distribute the attention over a series of discrete perceptions, as is shown by their immediate reproduction. In other words, it is the ability to grasp a number of different elements in one operation of attention." It is not only a test of discrimination or differentiation, but also a test of comprehension or coherence. These two latter abilities are included by Witmer[9] in his *Six Categories of Human Behavior,* and are related chiefly to intellectual ability. Experimental evidence points to the fact that this test correlates well with educability, at least in a negative way, i.e., that while a good span is not always indicative of good ability to do school work, a poor span is of diagnostic significance of inability to make satisfactory progress. This is supported by Leaming[11] in her study of the fifteen-year-old level, who states a forward span of 6 is necessary for successful high school work, but that it does not necessarily follow that all who have forward spans of 6 are equipped to do higher work. She also states that "it is of diagnostic significance if an individual of the fifteen-year-old group fails to give 4 or even 5 digits in reverse order."

Dr. Easby-Grave,[12] in her study of the six-year-old level, states that an audito forward memory span of 3 "should make the clinician suspect present or future retardation."

Memory span involves imagination, or the ability to get perceptions of the stimuli; immediate memory, in so much as the individual must retain the image long enough for reproduction; distribution of attention; and associability or ability to group; but the thing specifically tested by memory span is the co-functioning of these abilities.

It is quite evident that it is not always the same combinations of abilities that are called forth from every individual in response to this test. There are individual differences due to imaginal types and to the degree of complexity of intellectual organization.

Some individuals in their efforts to reproduce a series, either close their eyes or stare fixedly into space, and it is evident that they are transferring the auditory impression over to the visual field. Others move their lips or their tongues and are re-enforcing the impression through the kinæsthetic field. Others very glibly

reproduce the series in such a fashion that it seems evident they have had an auditory after-image. Some individuals, usually the more intelligent ones, obtain a large span by grouping the digits in series of 2's, 3's, or even 4's. This is evidence of the ability to organize, an ability required more and more of the child as he advances in school. In some few cases long spans are due to echolalia. In the entire 1,000 cases, however, in only 1 case, a little negro girl of 7 years, who gave a forward span of 8 digits and a reverse of only 2, was this discovered to be the cause.

Likewise, in giving digits in reverse order several methods are used. Some individuals depend on their good visual imagery, and by closing their eyes, or staring raptly before them, they rapidly "read" the digits in reverse order with great facility. This test is of least value when given to an individual who has this special ability of good visualization. With few exceptions, good results obtained by members of the backward group were due to the possession of this ability.

Other individuals depend largely upon their kinæsthetic verbal imagery, saying the number forward, then backward, and, if a series is complex, breaking it into groups, reversing one group at a time. Still others will "write" the digits with their fingers, or touch each finger to indicate a digit.

The reverse span seems to demand greater complexity of intellectual organization than the forward span. It requires a higher degree of comprehension. In contrast to the span which requires the ability to imitate, the reverse span involves a reorganization of perceptions. This requires more retention and concentration. The task of giving digits in reverse order is completely beyond the ability of most feeble-minded and dull children. They cannot comprehend the problem even though it be demonstrated for them. From all except those who are strong visualizers, this problem demands a high degree of intellectual organization. This problem demands some use of the intelligence for the individual must hit upon some device to help him accomplish this task and the more intelligent the child, the more successful he is. Although the ability to retain the forward series does enter into the problem, it does not necessarily follow that if the child can retain the forward order, he can reverse. In many instances the child repeated the forward order correctly, but could not reverse correctly. Furthermore, this does not seem to be a test that can be successfully taught to the child. If the child does not comprehend what is re-

quired, in very few instances does extra explanation or even actual suggestion as to method enable the child to be more successful.

The question as to which method the individual uses is not so significant in this instance, as is the fact that he has the ability to make the most efficient use of whatever ability he has. The very abilities he must use to pass this test are the same as those he must use in acquiring an education. He must not only possess discernment, he must also possess the ability to organize.

Most of our reasoning processes can be brought down to the ability to make discriminations, which is the power to differentiate and to see likenesses and differences. Locke says, "It is not enough to have a confused perception of something in general; unless the mind had a *distinct perception of different* objects and their qualities, it would be capable of very little knowledge." Growth in knowledge is a process of organizing our experiences, perceiving, conceiving and understanding them is ever more subtle differentiations and relationships.

This is another way of stating that all higher thought processes depend on our ability to analyze (differentiate) and to synthesize (associate or comprehend). James speaks of these two mental activities as being "the ultimate foundation pillars of the intellectual life."

Conclusions

1. Memory span is dependent on age and mental development.
2. The diagnostic value of the memory span test resides in its clear differentiation of the two extreme groups.
3. The reverse span test is more highly diagnostic than the forward span.
4. Mental development varies directly with the ratio of the reverse span to the forward span.
5. The memory span test is diagnostic of the complexity of mental organization and is a reliable educability test.

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